

WHAT IS CLAIMED IS:

1. A cholesteric liquid crystal cell unit receiving incident light, said unit comprising  
a first cholesteric liquid crystal cell receiving said incident light, said first  
5 cholesteric liquid crystal cell reflecting circularly polarized light of one state of said incident light or transmitting said incident light responsive to a control signal; and  
a second cholesteric liquid crystal cell arranged with respect to said first cholesteric liquid crystal cell to receive light transmitted by said first cholesteric liquid crystal cell, said second cholesteric liquid crystal cell selected to reflect or transmit light from said first  
10 cholesteric liquid crystal cell responsive to said control signal when said first cholesteric liquid crystal cell reflects said circularly polarized light of said one state or transmits said incident light respectively.
2. The cholesteric liquid crystal cell unit of claim 1 further comprising a  $\pi$ -  
15 phase waveplate element between said first and second cholesteric liquid crystal cells.
3. The cholesteric liquid crystal cell unit of claim 2 wherein said  $\pi$ -phase waveplate element comprises a third liquid crystal cell.
- 20 4. The cholesteric liquid crystal cell unit of claim 2 wherein said  $\pi$ -phase waveplate element comprises a plate of birefringent crystal material.

5. The cholesteric liquid crystal cell unit of claim 1 wherein said first cholesteric liquid crystal cell comprises a first cholesteric liquid crystal reflecting circularly polarized light in said one state, and said second cholesteric liquid crystal cell comprises a second cholesteric liquid crystal reflecting circularly polarized light in an opposite state.

6. An optical switch/attenuator device comprising

a first sleeve having a central longitudinal channel and an end face;

first and second optical fibers fixed in said first sleeve channel, said first and

10 second optical fibers each having end surfaces coincident with said first sleeve end face;

a first collimating GRIN lens having first and second end faces, said first end face proximate said first sleeve end face;

a second sleeve having a central longitudinal channel and an end face;

a third optical fiber fixed in said second sleeve channel, said third optical fiber

15 having an end surface coincident with said second sleeve end face;

a second collimating GRIN lens having first and second end faces, said first end face proximate said second sleeve end face, said second end face directed toward said second face of said first GRIN lens;

a cholesteric liquid crystal cell unit between said second end faces of said first and

20 second GRIN lenses, said cholesteric liquid crystal cell unit having

a first cholesteric liquid crystal cell receiving incident light from said first GRIN lens, said first cholesteric liquid crystal cell reflecting circularly polarized light of one state of said incident light or transmitting said incident light responsive to a control signal; and

a second cholesteric liquid crystal cell arranged with respect to said first cholesteric liquid crystal cell to receive light transmitted by said first cholesteric liquid crystal cell, said second cholesteric liquid crystal cell selected to reflect or transmit light from said first cholesteric liquid crystal cell responsive to said control signal when said first cholesteric liquid crystal cell reflects said circularly polarized light of said one state or transmits said incident light respectively;

said first and second sleeves, said first and second GRIN lenses, said cholesteric liquid crystal cell unit arranged and oriented with respect to each other so that light from said first optical fiber passes through, and back from, said first collimating GRIN lens, and said cholesteric liquid crystal cell unit into said second optical fiber when said cholesteric liquid crystal cell units reflects light responsive to said control signal, and light from said first optical fiber passes through said first collimating GRIN lens, said cholesteric liquid crystal cell unit, and said second collimating GRIN lens into said third optical fiber when said cholesteric liquid crystal cell units transmits light responsive to said control signal.

1                   7.       The optical switch/attenuator device of claim 6 further comprising a  $\pi$ -  
2 phase waveplate element between said first and second cholesteric liquid crystal cells.

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4                   8.       The optical switch/attenuator device of claim 7 wherein said  $\pi$ -phase  
5 waveplate element comprises a third liquid crystal cell.

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7                   9.       The optical switch/attenuator device of claim 7 wherein said  $\pi$ -phase  
8 waveplate element comprises a plate of birefringent crystal material.

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10                  10.       The optical switch/attenuator device 6 wherein said first cholesteric liquid  
11 crystal cell comprises a first cholesteric liquid crystal reflecting circularly polarized light in said  
12 one state, and said second cholesteric liquid crystal cell comprises a second cholesteric liquid  
13 crystal reflecting circularly polarized light in an opposite state.

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15                  11.       The optical switch/attenuator device of claim 6 further comprising  
16 a fourth optical fiber fixed in said second sleeve channel, said fourth optical fiber  
17 having an end surface coincident with said second sleeve end face; and  
18 wherein said first and second sleeves, said first and second GRIN lenses, said  
19 cholesteric liquid crystal cell unit arranged and oriented with respect to each other so that light  
20 from said fourth optical fiber passes through, and back from, said second collimating GRIN lens,  
21 and said cholesteric liquid crystal cell unit into said third optical fiber when said cholesteric

liquid crystal cell units reflects light responsive to said control signal, and light from said fourth optical fiber passes through said second collimating GRIN lens, said cholesteric liquid crystal cell unit, and said first collimating GRIN lens into said second optical fiber when said cholesteric liquid crystal cell units transmits light responsive to said control signal.

12. The optical switch/attenuator device of claim 6 wherein said cholesteric liquid crystal cell unit reflects light responsive to a first control signal voltage and transmits light responsive to a second control signal voltage and proportionally transmits and reflects light responsive to control signal voltages intermediate said first and second control signal voltages.

13. A WDM add/drop multiplexer comprising  
a first sleeve having a central longitudinal channel and an end face;  
a network input optical fiber;  
a network output optical fiber, said network input and output optical fibers fixed in said first sleeve channel and having end surfaces coincident with said first sleeve end face;  
a first collimating GRIN lens having first and second end faces, said first end face proximate said first sleeve end face;  
a second sleeve having a central longitudinal channel and an end face;  
an add optical fiber;  
a drop optical fiber, said add and drop optical fibers fixed in said second sleeve channel and having end surfaces coincident with said second sleeve end face;

a second collimating GRIN lens having first and second end faces, said first end face proximate said second sleeve end face, said second end face directed toward said second face of said first GRIN lens;

a wavelength-dependent filter proximate said second end face of said first collimating GRIN lens, said wavelength-dependent filter transmitting light at selected wavelengths and reflecting light at other wavelengths;

a cholesteric liquid crystal cell unit between said wavelength-dependent filter and said second end face of said second GRIN lenses, said cholesteric liquid crystal cell unit having

a first cholesteric liquid crystal cell receiving incident light from said first GRIN lens, said first cholesteric liquid crystal cell reflecting circularly polarized light of one state of said incident light or transmitting said incident light responsive to a control signal; and

a second cholesteric liquid crystal cell arranged with respect to said first cholesteric liquid crystal cell to receive light transmitted by said first cholesteric liquid crystal cell, said second cholesteric liquid crystal cell selected to reflect or transmit light from said first cholesteric liquid crystal cell responsive to said control signal when said first cholesteric liquid crystal cell reflects said circularly polarized light of said one state or transmits said incident light respectively;

said first and second sleeves, said first and second GRIN lenses, wavelength-dependent filter, and said cholesteric liquid crystal cell unit arranged and oriented with respect to each other so that light from said network input optical fiber at said other wavelengths passes through, and back from, said first collimating GRIN lens and said wavelength-dependent filter into said network output optical fiber, and so that that light from said network input optical fiber

66 at said selected wavelengths passes through, and back from, said first collimating GRIN lens,  
67 said wavelength-dependent filter, and said cholesteric liquid crystal cell unit into said network  
68 output optical fiber when said cholesteric liquid crystal cell units reflects light responsive to said  
69 control signal, and so that light from said first optical fiber at said selected wavelengths passes  
70 through said first collimating GRIN lens, said cholesteric liquid crystal cell unit, and said second  
71 collimating GRIN lens into said drop optical fiber when said cholesteric liquid crystal cell units  
72 transmits light responsive to said control signal, and so that light from said add optical fiber at  
73 said selected wavelengths passes through said second collimating GRIN lens, said cholesteric  
74 liquid crystal cell unit, said wavelength-dependent filter and said second collimating GRIN lens  
75 into said network output optical fiber when said cholesteric liquid crystal cell units transmits  
76 light responsive to said control signal.

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78 14. The WDM add/drop multiplexer device of claim 13 further comprising a  
79 optical fiber loop having first and second end sections arranged and oriented in said first sleeve  
80 channel so that light from said network input optical fiber at said other wavelengths passes  
81 through, and back from, said first collimating GRIN lens and said wavelength-dependent filter  
82 into said first end section and passes from said second end section through, and back from, said  
83 first collimating GRIN lens and said wavelength-dependent filter into said network output optical  
84 fiber.

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86 15. The WDM add/drop multiplexer device of claim 13 further comprising a  
87  $\pi$ -phase waveplate element between said first and second cholesteric liquid crystal cells.

1                    16.     The WDM add/drop multiplexer device of claim 15 wherein said  $\pi$ -phase  
2 waveplate element comprises a third liquid crystal cell.

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4                    17.     The WDM add/drop multiplexer device of claim 15 wherein said  $\pi$ -phase  
5 waveplate element comprises a plate of birefringent crystal material.

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7                    18.     The WDM add/drop multiplexer device of claim 13 wherein said first  
8 cholesteric liquid crystal cell comprises a first cholesteric liquid crystal reflecting circularly  
9 polarized light in said one state, and said second cholesteric liquid crystal cell comprises a  
10 second cholesteric liquid crystal reflecting circularly polarized light in an opposite state.

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12                   19.     An optical switch system comprising  
13 an array of input optical fibers;  
14 an array of first output optical fibers; and  
15 a switching matrix of cholesteric liquid crystal cell units, each liquid crystal cell  
16 unit reflecting or transmitting light selectively responsive to control signals and arranged with  
17 respect to said array of input optical fibers and said array of first output optical fibers so that light  
18 signals from an input optical fiber may be selectively reflected or transmitted by said liquid  
19 crystal cell unit into one of said first output optical fibers.



20. The optical switch system of claim 19 wherein said array of input optical fibers and said array of first output optical fibers comprise two-dimensional arrays, and said switching matrix of cholesteric liquid crystal cell units comprises a three-dimensional array.

21. The optical switch system of claim 19 further comprising an array of second output optical fibers, said array of second output optical fibers arranged with respect to said array of input optical fibers, said array of first output optical fibers and said switching matrix of cholesteric liquid crystal cell units so that light signals from an input optical fiber may be selectively transmitted or reflected by an liquid crystal cell unit into one of said second output optical fibers.

22. The optical switch system of claim 21 wherein said array of input optical fibers, said array of first output optical fibers and said array of second output optical fibers comprise two-dimensional arrays, and said switching matrix of cholesteric liquid crystal cell units comprises a three-dimensional array.

23. The optical switch system of claim 19 wherein each cholesteric liquid crystal cell unit comprises  
a first cholesteric liquid crystal cell arranged to receive incident light from an input optical fiber, said first cholesteric liquid crystal cell selectively reflecting circularly

41 polarized light of one state of said incident light or transmitting said incident light responsive to a  
42 control signal; and

43 a second cholesteric liquid crystal cell arranged with respect to said first  
44 cholesteric liquid crystal cell to receive light transmitted by said first cholesteric liquid crystal  
45 cell, said second cholesteric liquid crystal cell selected to reflect or transmit light from said first  
46 cholesteric liquid crystal cell responsive to said control signal when said first cholesteric liquid  
47 crystal cell reflects said circularly polarized light of said one state or transmits said incident light  
48 respectively.

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50 24. The optical switch system of claim 23 further comprising a  $\pi$ -phase  
51 waveplate element between said first and second cholesteric liquid crystal cells.

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53 25. The optical switch system of claim 24 wherein said  $\pi$ -phase waveplate  
54 element comprises a third liquid crystal cell.

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56 26. The optical switch system of claim 24 wherein said  $\pi$ -phase waveplate  
57 element comprises a plate of birefringent crystal.

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59 27. The optical switch system of claim 23 wherein said first cholesteric liquid  
60 crystal cell comprises a first cholesteric liquid crystal reflecting circularly polarized light in said

one state, and said second cholesteric liquid crystal cell comprises a second cholesteric liquid crystal reflecting circularly polarized light in an opposite state.

28. The optical switch system of claim 20 wherein said switching matrix of cholesteric liquid crystal cell units comprises a plurality of cholesteric liquid crystal cell unit mounting plates, each cholesteric liquid crystal cell unit mounting plate having at least a one-dimensional array of said cholesteric liquid crystal cell units and arranged at an angle with respect to said array of input optical fibers and said array of first output optical fibers.

29. The optical switch system of claim 28 wherein at least one of said cholesteric liquid crystal cell mounting plates has a two-dimensional array of said cholesteric liquid crystal cell units.

30. The optical switch system of claim 29 wherein said switching matrix comprises a plurality of separation plates, each separation plate separating two cholesteric liquid crystal cell unit mounting plates.

31. The optical switch system of claim 30 wherein said switching matrix comprises said cholesteric liquid crystal cell units arranged in a cube.

81                    32.     The optical switch system of claim 20 wherein each array of input optical  
82     fibers and first output optical fibers comprises a plurality of collimating GRIN lenses, each  
83     GRIN lens proximate ends of said input optical fibers and first output optical fibers.

85                    33.     The optical switch system of claim 20 wherein each array of input optical  
86     fibers and first output optical fibers comprises a plurality of collimating microlenses, each  
87     microlens proximate ends of said input optical fibers and first output optical fibers.

90                    34.     The optical switch system of claim 20 wherein each array of input optical  
91     fibers and first output optical fibers comprises  
92                    a first plate having a surface with a plurality of V-grooves therein; and  
93                    a second plate having a surface with a plurality of V-grooves therein, said second  
94     plate V-grooves matching said first plate V-grooves;  
95                    said first and second plates fixed together so that said V-grooves form channels  
96     holding a linear array of optical fibers.

98                    35.     The optical switch system of claim 34 further comprising a plurality of  
99     said first and second plates fixed together and arranged in a stack to form a two-dimensional  
100     array of optical fibers.

102                    36.     The optical switch system of claim 22 wherein said switching matrix of  
103 cholesteric liquid crystal cell units comprises a plurality of cholesteric liquid crystal cell unit  
104 mounting plates, each cholesteric liquid crystal cell unit mounting plate having at least a one-  
105 dimensional array of said cholesteric liquid crystal cell units and arranged at an angle with  
106 respect to said array of input optical fibers, said array of first output optical fibers and said array  
107 of second output optical fibers.

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109                    37.     The optical switch system of claim 36 wherein at least one of said  
110 cholesteric liquid crystal cell mounting plates has a two-dimensional array of said cholesteric  
111 liquid crystal cell units.

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113                    38.     The optical switch system of claim 37 wherein said switching matrix  
114 comprises a plurality of separation plates, each separation plate separating two cholesteric liquid  
115 crystal cell unit mounting plates.

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117                    39.     The optical switch system of claim 38 wherein said switching matrix  
118 comprises said cholesteric liquid crystal cell units arranged in a cube.

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120                    40.     The optical switch system of claim 22 wherein each array of input optical  
121 fibers, first output optical fibers and second output optical fibers comprises a plurality of

122 collimating GRIN lenses, each GRIN lens proximate ends of said input optical fibers, first output  
123 optical fibers and second output optical fibers.

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125                   41.     The optical switch system of claim 22 wherein each array of input optical  
126 fibers, first output optical fibers and second output optical fibers comprises a plurality of  
127 collimating microlenses, each microlens proximate ends of said input optical fibers, first output  
128 optical fibers and second output optical fibers.

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131                   42.     The optical switch system of claim 22 wherein each array of input optical  
132 fibers, first output optical fibers and second output optical fibers comprises  
133                   a first plate having a surface with a plurality of V-grooves therein; and  
134                   a second plate having a surface with a plurality of V-grooves therein, said second  
135 plate V-grooves matching said first plate V-grooves;  
136                   said first and second plates fixed together so that said V-grooves form channels  
137 holding a linear array of optical fibers.

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139                   43.     The optical switch system of claim 42 further comprising a plurality of  
140 said first and second plates fixed together and arranged in a stack to form a two-dimensional  
141 array of optical fibers.